FORMING

ROLL-FORMING STEEL STRIP

TECHNICAL BULLETIN FTB-5

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1 THE ROLL-FORMING PROCESS

Roll-forming is a process by which strip is passed through a number of pairs of mated profile rolls. The strip is either unwound from a coil or sheet fed into the machine. Each roll pair is designed to progressively develop a profile by predetermined increments *(Figure 1)*.

Roll-forming is a high productivity process capable of achieving close tolerance control, provide economy in labour and materials and has the ability to produce long continuous lengths and profiles of a complexity beyond the capacity of the press bending process.

In roll-forming, rolls gradually and progressively change the shape of a section, but the thickness of the metal generally remains constant and equal to that of the flat strip being fed into the machine.

Thus it is a bending not a stretching process, nor a rolling process in the usual sense in which a material is squeezed between rolls to reduce thickness. The gap between forming roll surfaces is ideally equal to (in practice always slightly greater than) the overall thickness of the material so that no reduction can take place. In fact, any presence of cold reduction in a roll-forming process is highly undesirable. It is often caused by some malfunctioning such as material pick-up by rolls, incorrect roll setting with regard to height or alignment, bad design or bad manufacture.

Roll-forming machines can produce sections of almost any shape and dimension, consistently and within close tolerances.

Roll-forming equipment, tooling and power usage are relatively expensive. In assessing the viability of roll-forming a profile which could be produced by alternative methods, the following points must be considered:

- Relative costs of equipment, tooling and labour
- Relative production rates of satisfactory product
- Volume requirement.

The variety of products roll-formed from steel strip and their fields of applications in all types of industry are almost infinite. Some idea of the variety of section profiles which can be roll-formed is given in Figure 2.

When purchasing or setting up a roll forming line, it is very important to have set up charts. These charts should tell the operator:

- Where the critical alignment points are for string lining
- Roll gaps for each stage and where to measure these gaps
- Alignment procedure for idler rolls
- Alignment and setting procedure for shears and other equipment used on the line.

Figure 1 – Typical roll-forming stages

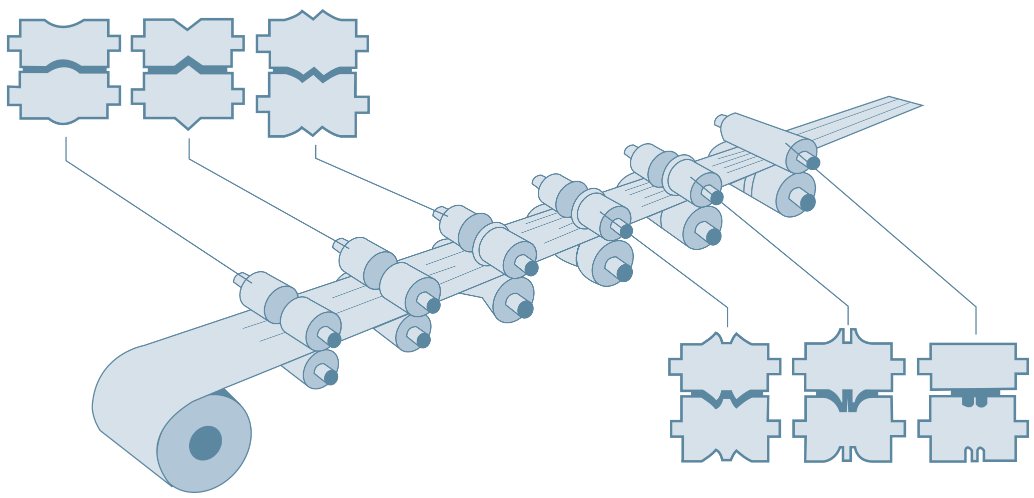
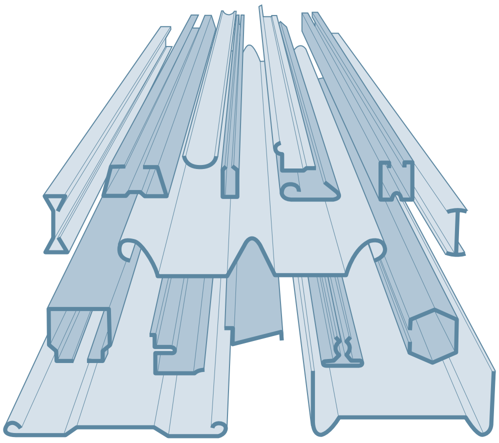


Figure 2 – Typical examples of sections produced by roll-forming



2 EQUIPMENT

The forming unit is normally a part of a complete roll-forming line which consists of an uncoiler, a cut-off device and a run-out or stacking table. Some lines incorporate a roller leveller, pre-punch unit and embossing unit often located between the uncoiler and the roll-former.

2.1 UNCOILER

If the roll-former is to be coil fed, then a means of holding the coil and paying off sufficient material is required. An uncoiler usually performs this task.

There are a number of uncoiler types: cantilever, cone, cradle, pallet and capstan. The cantilever uncoiler is most often used in high production roll forming because of the ease in loading and unloading coils. Mandrel expansion can be either powered or performed manually.

Uncoilers can be either driven, in which case a control is required to pay off the material at the correct rate, or un-driven. The un-driven uncoilers rely on the roll-former to provide the power to unwind the coil. For un-driven uncoilers a drag brake is required to stop material being spilt onto the ground.

2.1.1 COIL CAR

A coil car is often used in conjunction with an uncoiler to load and unload the coils. The coil car can increase throughput and also free up lifting equipment that would otherwise be waiting for the coil change.

2.1.2 UPENDER

Where coils are delivered bore vertical, and the roll former requires bore horizontal for operation, then upenders are required. A properly designed upender can change from bore vertical to bore horizontal quickly and safely and eliminate damage to the coil outer wraps.

2.1.3 PRE-PUNCHING / NOTCHING

Some profiles, such as purlins have holes pre-punched *(punched while the strip is flat, before it enters the roll-former)* for the attachment of bridging and for securing to the main roof structure.

Other sections may require cut outs for assembly or for ease of cutting after forming and these cut outs are often punched into the material before roll-forming. Suitable control equipment is required to enable the pre-punching units to operate in line.

2.1.4 OTHER

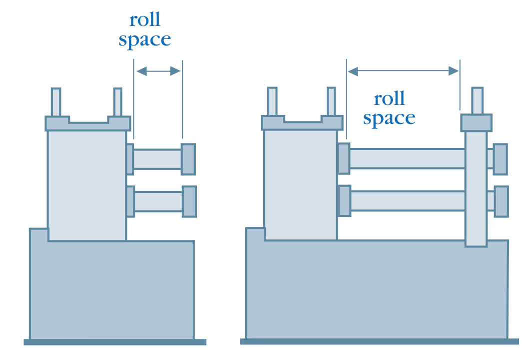
Other processes can be incorporated into the roll-forming line. These can include levellers to condition the material before forming, branding for recording the part number and manufacturers details, embossing to form a decorative pattern in the steel, welding or other joining techniques and pressing or folding operations after roll-forming.

2.2 FORMING STANDS

A roll-forming machine consists of several stands, usually from 4 to 20 or more, each supporting a pair of spindles *(generally driven)* which carry forming rolls. Small shapes are often produced with cantilevered *(over-hung)* spindles, convenient for quick roll changes. Medium and large sections require greater forming forces, therefore the spindles need to be supported at each end.

These two basic designs are shown diagrammatically in Figure 3.

Figure 3 – Two basic roll-forming machine designs



(a) Cantilevered roll spindles *(for small sections)*

(b) Fully supported roll spindles *(for medium to large sections)*

On the fully supported type, the inboard supports are fixed to the machine bed in a permanent fashion whereas the outboard stand is made easily removable for roll changing. An alternative to this is where the rolls and spindles are removed from the stands for roll changing. This requires the bridge caps to be removed and the rolls and spindles removed with a crane or other suitable lifting device.

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Rolls are generally driven on the inboard side either by a gearbox within the stand itself, by a separate gearbox to each stand or by 1 or 2 gearboxes and chains driving the remaining stages. To drive both top and bottom spindles, either double output gearboxes or gears within a stage can be used.

Single purpose units made for mass production of a single profile can be of much simpler construction without the need of provision for a rapid roll change. The drive system can be less elaborate and may be by chain and sprockets or exposed spur gears.

Alternatively, if a frequent change from one shape to another is required, roll-formers may be provided with removable magazines *(also called cartridges)*. Separate magazines carry several stands with fitted and preset rolls, ready for production. Re-connection of magazines may take some 20 minutes, as against several hours for conventional roll change and alignment.

2.3 CUT - OFF DEVICES

When purchasing a new roll-forming line, consideration needs to be made on whether the line will be pre-cut or post-cut. Pre-cut lines have a cut-off, usually a shear, located before the roll-former and are effectively sheet fed lines. Post-cut has the cut-off at the end of the roll-former.

The main advantage of pre-cutting is the simple cut-off shear that does not change when the profile is changed. The main disadvantages are the minimum sheet length *(3 times the stage spacing)* and extra care is required when designing the tooling to avoid damaging the leading and trailing ends. This usually results in additional stages being required when compared to post-cut machines.

The advantages of post-cutting are the shorter roll-former length, and the minimum cut-off length is usually limited by guards and other safety factors. The post-cut shear is however more complex, expensive and is profile dependent.

The cut-off devices used in post-cut operations can be a saw, an abrasive disc, or a flying punch and die cut-off unit. The latter type is used for high capacity production since the line does not have to be stopped to effect a cut. Either an adjustable limit switch, or a signal from an encoder actuates the press automatically. The limit switch, which governs the length of the product, is located on the run-out table. The encoder, located within the roll-former, sends a signal to a PLC or computer which in turn tells the shear when to cut.

The disadvantages of flying cut presses are the relatively high cost, high noise and the need for an individual pair of cutting blades for each profile produced.

An improvement in computing and electronic equipment and restrictions on noise limits has resulted in the flying cut no longer being the preferred method. Slow down to cut and stop to cut units are becoming more popular as they are quieter and more cost effective.

Saw cutting is suitable for very thick feed or for closed profiles. A de-burring operation is usually required after sawing, especially if an abrasive disc is used. A slug punch shear is suitable for generally open profiles of approximately 100 mm depth and up to 3 mm metal thickness. Swing or straight shearing eliminates slug waste and slug disposal and is used on open sections.

2.4 STRAIGHTENING EQUIPMENT

Residual stresses from the forming process are not usually symmetrical and provision of equipment which can be adjusted to correct torsional, vertical and horizontal misalignment in the as-formed product is essential.

Straightening may be by an adjustable die plate or by roller units in adjustable housings.

2.5 FORMING ROLLS

The main forming rolls can be either split or solid *(Figure 4)*. With split rolls the desired profile at each stage is built up from a number of segments whereas the solid is one roll shaped to the required profile.

The split roll is the more widely used of the two because:

a) roll manufacture is simpler

b) rolls can be designed for hardening and not just to satisfy section profile

c) if a roll is damaged or badly worn only one segment needs to be replaced, such as a part susceptible to wear or damage

d) modifications can be easily and cheaply effected

e) some rolls such as cone rolls or base rolls can be used on a variety of sections.

Split rolls are built up from individual segments which are tightened onto the spindle by a nut at the outboard stand to produce the required roll shape. For relatively small production runs of simple shapes, rolls can be made of unhardened, low carbon steel. Cast iron, laminated plastic and even hardwood can be used. The last two or three forming stages are usually made of steel.

For high production and longer tool life, rolls are made of high quality tool steel, usually hardened to 60 HRC and ground after heat treatment. Non-working roll segments and spacers can be made of lower quality steel.

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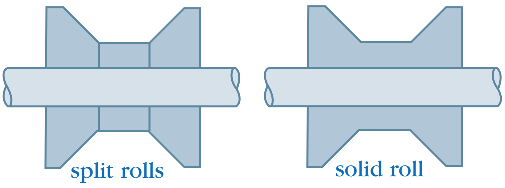
Recent trends in wide panel forming machines has seen the use of high tensile steel which can be readily surface hardened. The rolls are usually hardened after commissioning trials.

Before the rolls are placed in production, they are normally assembled on dummy spindles *(or their own spindles)* and checked for accuracy of dimension and alignment. A wire of a diameter equal to the thickness of sheet to be formed can be passed between working faces of assembled top and bottom rolls to verify matching of surfaces.

Figure 4 – Roll-former roll types



3 ROLL DESIGN

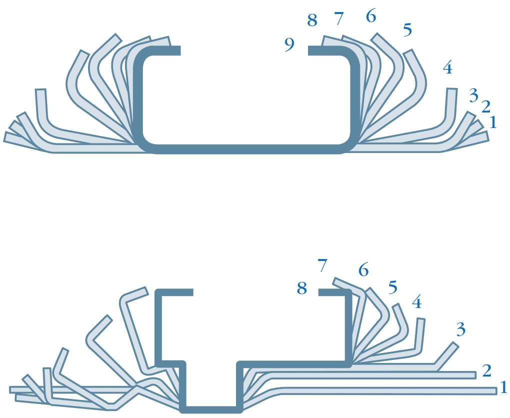
In addition to the cross-sectional size and shape of the product, factors which affect roll design are steel strip thickness and width tolerance, steel grade, strip edge condition, required finish and accuracy, and the anticipated production volume.

All these items must be finalised before detail work is attempted.

Basic design begins with an assessment of the required number of forming stages *(driven rolls and idlers)* and individual configurations. In order to visualise the progress from flat strip to final shape, intermediate shapes can be drawn superimposed, whereby one obtains flower diagrams such as shown in Figure 5.

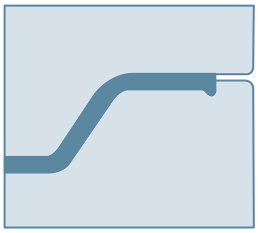
Detailed consideration must be given to the inward flow of material between the forming stages. Too sudden a transition from one shaped stage to the next can cause longitudinal stretching of the material. This can introduce residual stresses and give rise to a bow or twist in the final product.

Figure 5 – Development flower diagrams

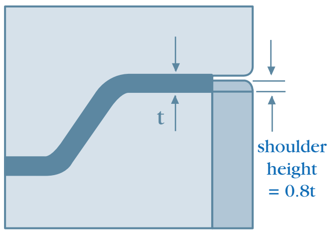


The material must be guided laterally throughout the roll-former. Initial location and subsequent guiding are provided by the entry guide, but additional guides may be required between some forming stages. Further guiding is generally carried out by the forming rolls themselves, as the portion of section already formed can provide an adequate lateral location in subsequent stages. Guiding can also be achieved by provision of locks on the periphery of rolls as shown as Figure 6.

Figure 6 – Guiding locks in rolls



(a) Lock recessed in bottom roll



(b) Locking by a separate roll segment is a better solution

Rolls with locks are not popular among manufacturers as they are more costly to make and require strip feed slit to close tolerances. Mill edge hot-rolled strip with a very wide width tolerance for instance, is quite unsuitable for guiding by roll locks. Where a feed with a wide width tolerance must be accommodated, the best solution is a self-centring entry guide and rolls designed to provide adequate guiding properties.

Ideally the peripheral speed of rolls closely equals the speed of the material advancing through the roll-former *(roll-former speed)*. However, as the roll diameters vary across their width to suit the contour of each forming stage, the peripheral speed of rolls is not constant and thus cannot be made equal to the roll-forming speed at each point. Rather, an average or nominal pitch roll diameter only can be matched with the material speed, and the designer's task is to determine such a diameter for each pair of rolls. As a guide, the pitch diameter can generally be taken as that of the centroid of profile.

Rolls for deep profiles have a great discrepancy between pitch diameter and maximum or minimum working roll diameter. This results in a substantial speed differential between working surfaces, associated with heavy rubbing which can give rise to product scuffing and/or excessive roll wear.

One remedy is good lubrication at the critical spots *(pump propelled jets of coolant/lubricant are commonly used)*. Other methods include felt wicks, and drip lubrication. Where possible lubricants should be used sparingly. A number of idler rolls on suitably angled spindles or individual rolls mounted on bearings can also be used to reduce scuffing.

Any idler roll adjusts itself to the optimum speed automatically and its mean diameter is not critical. Sometimes rubbing can be minimised by suitable orientation of the product shape to reduce maximum roll diameter, and consequently, differential speeds between surfaces.

4 ROLL-FORMER DESIGN VERSUS PRODUCT DESIGN

This is the most important phase of roll-forming since errors in tooling design can result in high rejection losses, costly down-time on the mill and little saleable product.

Unfortunately, there are few specific rules which can be applied to the design of roll profiles which will vary greatly with complexity of section shape. Selection of the number of stands, degree of bending per stand and such factors will generally be based on the experience of tool designers. For simple shapes such as channels or angles, standard roll-sets are available commercially, but for jobbing work on more complex shapes, in-house design of roll profiles is usually required. It is possible to give a few general guidelines to indicate some of the factors which influence the design of roll-forming rolls.

4.1 DESIGN OF THE FORMING STAGES

4.1.1 DESIRED SECTION

The section drawing should be complete in specifying all pertinent information relative to the dimensions and quality of the required product. Tolerances must be known.

As well as product dimensions the designer should consider longitudinal and cross bow, camber and end flare and how these will affect the end use of the profile. Specification of tolerances for these attributes can assist the designer in selecting an appropriate number of stages and is beneficial when acceptance trials are conducted.

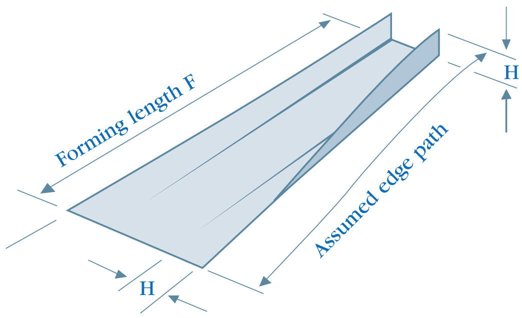
4.1.2 DETERMINATION OF FORMING LENGTH

The forming length is the distance between the last point of unformed material and the point at which the final form is completed.

For a simple channel of flange height H, *(Figure 7)* the forming length may be calculated by F=40 H. This assumes that if the feed edge were to follow a straight line in its flow through the forming stages, the edge strain would be 0.06% which is less than the elastic strain limit of steel. In practice the edge path will be longer than the ideal. For complex profiles the determination of the forming length will be based on extending the above geometrical approach, using imagination and experience to devise a forming sequence which will not induce plastic strain in unformed elements of the profile. The use of higher tensile material for roofing and walling product, has resulted in modification of this rule by some designers to 70 or 100 H.

The continual improvement in computer technology has seen the introduction of design packages for roll forming. These packages range from simple straight-line approximations of material movement through to more sophisticated analysis techniques. These packages can be used to determine the number of stages and the flower diagram.

Figure 7 – Forming path



4.1.3 DETERMINATION OF THE NUMBER OF FORMING STAGES

Assume a simple channel with a 50 mm flange is to be roll-formed through forming stations at 400 mm intervals.

First estimate the required forming length from above:

F	=	40 x 50
	=	2000 mm

Then from this, the number of station spacings to give the number of stations:

Station spacings	=	2000 ÷ 400
	=	5 station spacings
	=	6 stations

It is necessary to include an additional station to fix the final profile, therefore a total of seven stations is required.

4.1.4 DETERMINATION OF FORMING SEQUENCE

Station 1 will normally be used to align the flat feed with the subsequent forming stations. All forming stages are important but the final stages should be designed to give a smooth exit to the section rather than sharp profile changes immediately before exit.

Two alternatives of forming a 50 mm leg channel illustrate the usefulness of a flow plan *(Figure 8)* in showing the general flow pattern. For complex flow plans, several significant points may be drawn for a considered forming approach and studied to determine whether the flow pattern appears satisfactory or indicates where modification would be desirable.

Figure 8 – Flow plans

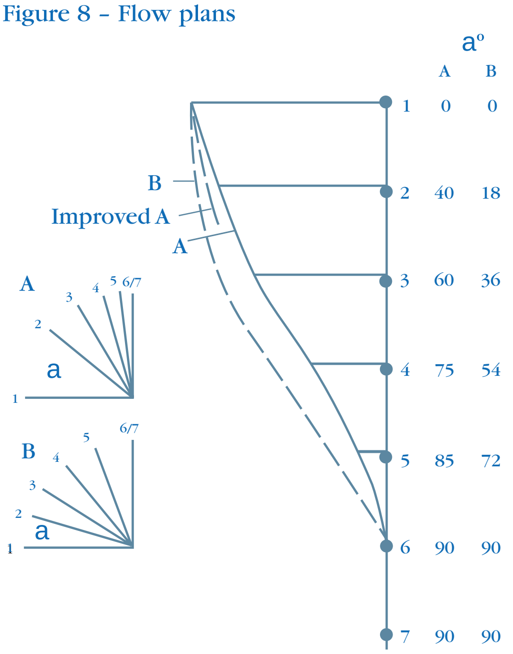


Figure 8 shows that sequence A is preferred because it gives a much better exit than sequence B. Sequence A may be improved if a is reduced slightly in stage 2.

In determining a forming sequence, the properties of the sheet material need to be considered.

For soft material such as G300, some designers use:

a) a reasonably large forming angle in the early stages.

b) radii larger than final form radii in early forming stages.

These two factors are sometimes combined to produce quite a large degree of lazy form at the early stage. Usually, vertical offset is also introduced to promote a smooth flow of feed to optimise concentrated forming.

For softer materials some designers prefer to use:

a) bend angles selected to give a smooth material flow; or

b) constant bend radii throughout the forming stages.

For high tensile material it is generally desirable to use:

a) bend angles selected to give a smooth material flow, with reasonably small forming angle in the early stages; or

b) constant bend radii throughout the forming stages.

Extra stages are often required when forming the higher tensile material to overcome its additional springback.

Good roll-forming will always require proper consideration of the forming sequence, careful alignment of uncoiler and all forming stations, provision of side guides to promote smooth flow, provision for correcting springback, adequate straightening equipment and an efficient cut-off. A little extra assistance to ensure good forming is far less costly than losses in time, scrap and goodwill when chances are taken by minimising forming passes and auxiliary equipment.

It is very important to ensure the roll design provides for the necessary profile length elements *(transverse)* so the profile will be developed by bending and not by stretching. Where stretching does occur there will be a thickness reduction at the bend radius rather than in the unbent areas. There is also an increase in power required for machines that stretch form. Normally this is minor but if sufficient stretching occurs power consumption can increase dramatically. This thickness reduction causes a decrease in the length of the bend *(refer Figure 9)* and the stress imbalance across the profile can result in a variety of shape problems, eg. oil canning. While this condition can be recovered in ductile steels by ensuring the rolls iron, and so extend the material in the bend, the same recovery cannot be applied to high strength products as discussed later. Care should be taken when ironing the bends when using organic and or metallic coated sheet steel. The ironing can affect the life of these coatings.

Careful alignment of forming stages is essential to minimise the possibility of excessive reforming in the vicinity of bends. Correct alignment of the lower spindle rolls may be achieved by relating a selected point on the forming roll profile to a common datum line through the mill. This datum point may be on the faces of the inboard rolls which abut accurately aligned roll spindle shoulders. A stretched nylon fishing line can be used to provide a datum line through the mill for setting the positions of each roll.

Roll station drawings should include a specific dimension from the selected profile point to the datum point which is used in the setting up of the stations.

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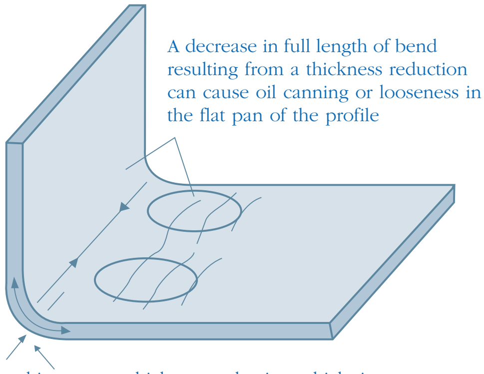
Figure 9 – Effect of transverse stretching of bends in a roll-formed profile



Top spindle rolls should be checked for proper mating with the aligned lower roll profile. A thin, flat strip of feed material or feeler gauges can be used as a gauge to ensure that feed will have sufficient clearance to pass between the mating roll profiles and not be subjected to ironing which may locally stretch the material and cause oil-canning, edge wave or rippling.

Careful appraisal of space requirements should be made to ensure efficiency. Relating production rate of the mill to take off and disposal of product will ensure correct space and handling allowances. A smooth, comfortable running speed continuously maintained is less fatiguing for operators and equipment than stop-start operation and overall production rate will be higher.

The section drawing should be the focus for all production considerations. It should give all necessary information for feed supply, mill selection, and tool design. The application of tolerances should be rational. Roll-formed profiles can be held to very close tolerances which are important when there is assembly with other components.

There are many requirements, however, where quite liberal tolerances may be acceptable. If so, it is unnecessary and costly to specify closer tolerances which may result in high scrap and low throughput.

Where a roll-formed section is to be further processed *(such as holed, notched, welded)* this information should be indicated on the section drawing to properly relate the product through the production phases.

4.2 ALLOWANCE FOR SPRINGBACK

The springback effect due to the elastic recovery of the steel strip can be allowed for by overbending. This is normally done in the later stages by side guides or vertical spindle rolls. The amount of springback is dependent on many factors:

a) geometry of section - material thickness, bend radius, bend angle and neutral axis shift;

b) steel characteristics, i.e., yield strength and thickness;

c) degree of conformity of section to contour of rolls; and

d) type of bend and how formed. For example, a bend or radius in the base of a section can be stretched in if the strip edges are held. This induces tension in the material, and if excessive, causes permanent set.

If the same radius is formed without the edges being held, little tension is induced. Thus the amount of springback in the latter case would be greater and increased overbending will be required to form the design profile. Where transverse stretching is applied to the feed as the bend is being formed the springback effect is reduced and stretching of the feed will occur in the areas being bent *(refer Figure 9)*. This will mean that the bends will be shortened and there will be a tendency to develop oil canning or looseness in adjacent flat pans. This tendency can be a considerable problem when using thin high strength feeds.

4.3 FEED WIDTH

The width of strip feed for a roll-forming operation can be determined by adding together the length of the flat elements of a roll-formed shape and a length calculated from standard formulae or tables for bend allowances. This information is readily available in standard texts on roll-forming.

4.4 GENERAL CONSIDERATIONS

It is possible to roll-form almost any profile, but some shapes are inherently less troublesome to produce or necessitate less costly rolls than others. Thus, designers of new structural profiles in particular, should familiarise themselves with the fundamentals of roll-forming techniques and consider the formability as one of the design parameters.

The following additional information is provided as a roll-formed product design aid:

a) profiles should be preferably open with side angles at less than 90° *(trapezoidal shapes);*

b) where possible, one edge of the profile should be free, that is, dimensions and bend angle in the vicinity thereof should not be critical. This will allow for feed width inconsistencies and provide a scope for compensation of some other possible irregularities which may become evident in trial runs;

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c) wide, unsupported flats along either edge should be avoided. They cannot be easily controlled in the roll-forming process and are not structurally sound anyway;

d) sometimes it is difficult to eliminate residual stresses even with great care in roll design and setting; for example, roll-forming of roofing and walling sheets which have wide flat areas *(pans or trays)* in their profiles. One remedy is the introduction of one or two longitudinal flutes *(shallow ribs)* in the pans, which may not completely eliminate residual stresses but are effective in suppressing or hiding the oil-canning tendencies. The shallow flutes often may be drawn rather than formed; and

e) structural and many other practical considerations call for bend radii *(inside radii of bends)* to be as small as possible, consistent with the steel thickness and ductility. Manufacturer's data sheets should however be consulted before the design is finalised to determine recommendations.

If a material is bent to a radii greater than that specified in BlueScope Steel's Product Data Sheets with no cross tension or base metal thinning, then no cracking should be observed on the bends of the metallic and painted coatings. However, if the bend radii are too tight, the paint and or metallic coating may crack as shown in Figures 10a, b and c. Paint cracking on light colours can be readily seen with the naked eye or using a 10x magnification eye-piece as shown in Figure 10a. In general, on similar bend radii, lighter colours tend to exhibit more paint cracking than darker colours. Also, strip temperature has an effect on the potential for paint cracking ie. more severe cracking will occur on colder strip. NOTE – T-Bend adhesion and cracking details quoted in relevant Product Data Sheets, are based on tests performed at a temperature as specified in AS/NZS 2728:2007 i.e. 23 +/- 5 deg C.

Figure 10a. - Magnified view (10x) of a roll formed bend showing areas of cracking of the paint.

Figure 10b. - Cross section of roll formed bend (0.42mm bmt) with cracking of the paint.

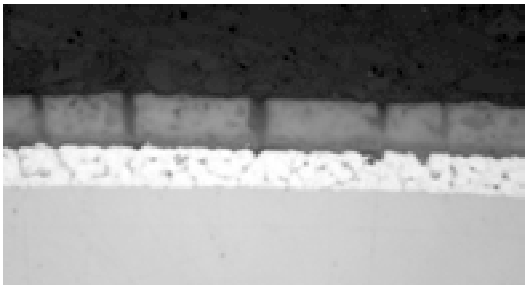
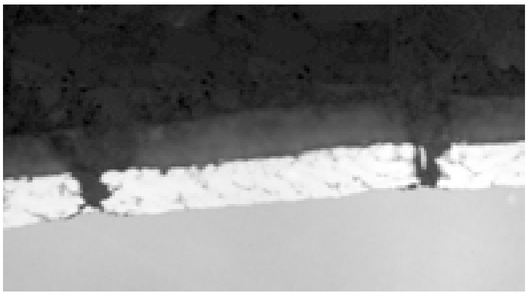


Figure 10c. Cross section of roll formed bend (0.42mm bmt) with cracking of painted and metallic coatings.



The various stands of a roll-forming machine need to be positioned to ensure that the flow of material into the final shape is carried out as smoothly as possible. In particular, the following should be avoided:

a) excessive forming on any particular stand which results in unnecessary stretching of the base material often called "bend thinning". Figure 11 shows a cross section of a bend with excessive bend thinning, while Figure 12 shows a bend with minimal stretching.

Figure 11 - Cross section of roll formed bend (0.60mm bmt) with excessive bend thinning.

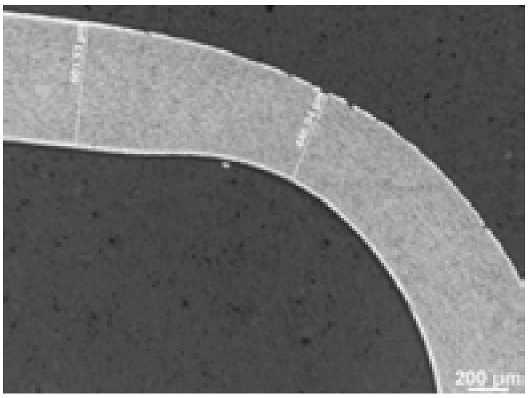


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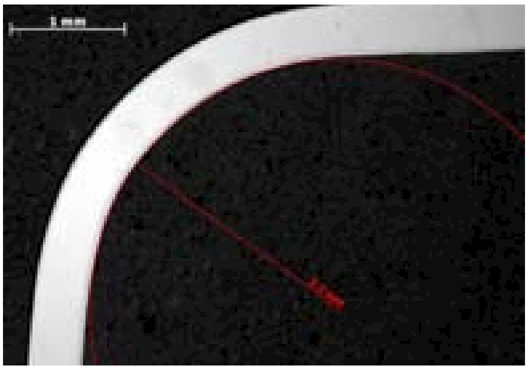
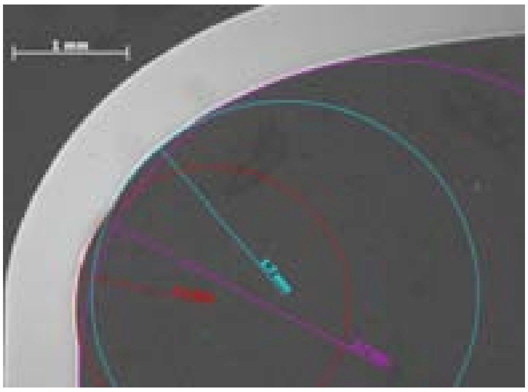
Figure 12 - Cross section of roll formed bend.



b) inaccurate positioning of the stands in relation to the flow of material, resulting in re-rolling of the shape. This occurs where a particular point of forming varies from stand to stand, resulting in material being flexed backwards and forwards, weakening the bond of the coating as well as deforming the base metal as shown in Figure 13. This nominally 3 mm radius bend is composed of a number of tighter bends.

Figure 13 - Cross section of roll formed bend.



Severe bend thinning will significantly reduce the strength of the base metal and may result in splitting and/or other defects of the material.

Any roll forming tooling needs to be regularly maintained. Tooling should be checked for wear and or damage on a regular basis. Careful alignment of forming stages is essential to minimise the possibility of excessive reforming in the vicinity of bends.

When purchasing or setting up a roll forming line it is very important to have set up charts. These charts or drawings should tell the operator:

a) The datum point which is used in the setting up of the tooling.

b) Roll gaps for each stage and where to measure these gaps

c) Alignment procedure for idler rolls

d) Alignment and setting procedure for shears and other equipment used on the line.

5 ROLL-FORMING ORGANIC FINISHED STEEL STRIP

Organic-finished pre-painted strip is well suited for roll-forming because of the lubricity of the various coating types. However, common sense precautions are necessary to ensure a satisfactory performance of the coating. As is the case when roll-forming any suitable type of steel strip, the more forming stages, the greater the ease of forming. Unnecessary deformation of the steel base can destroy the adhesion of the coating and therefore suitable roll-former design is necessary. Roll-former settings are mostly based on experience, with adjustments being dictated by observation and the state of the emerging formed product. As a general guide, settings for organic-finished steel strip should be calculated on the thickness of the metal substrate only

(the steel plus any metallic coating present) with the following considerations:

a) For COLORBOND® pre-painted steel strip, disregard the thickness of paint coating. If a coating of strippable polyethylene film is present (CORSTRIP®), add 80% of polyethylene film thickness.

b) COLORBOND® steel products should be roll-formed dry. If a lubricant is considered necessary for the painted surface of COLORBOND® steel, SHELLSOL T (or material with equivalent specification) should be used sparingly.

c) Where COLORBOND® steel products carry a strippable polyethylene film no additional lubrication is required as the polyethylene film acts as a solid lubricant.

d) Roll-formers should be cleaned free from all traces of lubricants and metal debris which may be present from any proceeding runs.

This is particularly important for roll forming COLORBOND® steel products after galvanised material. Zinc particles from the galvanised material can be transferred to the COLORBOND® steel product by the roll former tooling and result in unsightly dark markings on the painted surface.

6 ROLL-FORMING HIGH STRENGTH STEEL STRIP

While the reduced ductility and higher yield strength of the various uncoated and coated high strength products ensures these cannot be always successfully formed by conventional roll-forming processes, experience gained in recent years has provided the understanding of both product characteristics and roll-forming techniques to allow the production for a large

BLUESCOPE STEEL

range of cladding and rainwater goods profiles from high strength feed. The advantages of these products are not only higher strength and hence, reduced thickness, but decreased damage during transportation, installation and service.

These products are mainly ZINCALUME® G550, ZINC HI-TEN® G550, ZINC HI-TEN® G500 and ZINC HI-TEN® G450.

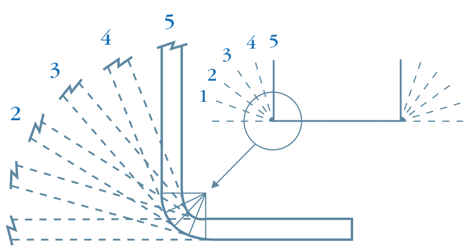
6.1 COMPARISONS WITH CONVENTIONAL FORMING

While high ductility, low strength products are most readily roll-formed to structural sections this ductility is associated with a low yield strength which has an adverse affect on the load bearing performance of the sections. The increase in strength obtained by using cold rolled stress relieved strip feed such as ZINC HI-TEN® G500 and G450 steel is the most economical and practical way to produce a high strength section, and the roll-forming industry is very able to produce the channel and "Z" shapes required by this market.

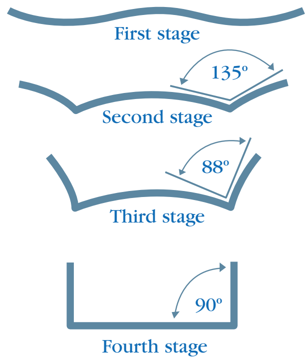
Naturally, these high strength products cannot be formed adequately using rolls designed to form the ductile products and the following comments provide an indication of the changes to roll design concepts which are required to produce these shapes.

One of the first lessons learned in roll-forming high strength steels is that bends cannot be readily reformed. The normal method for ductile steels, Figure 14a, is to progressively develop a bend from the adjacent unformed flat, or to gradually reduce the radius. Up to five stages may be used for a 90° bend. Such gradual bend development allows the surrounding material to travel through the roll-former in a slow sweep, thus minimising stretching near the toes of the channel and residual stresses in the finished product. When forming a channel of high strength steel, a similar method can be used. The use of variable radii forming should however be avoided as the extra springback of the G550 material can cause problems. The springback of the G550 material can mean that the initial stages are operating in the elastic region and the latter stages are required to do far more work than the designers intended.

Figure 14 – Forming methods for ductile and high strength steels



(a) Conventional forming of ductile steels



(b) Example of forming of high strength steels

In any set of tooling, care is required in tooling alignment to ensure that re-rolling does not occur as splitting may result.

Figure 14b shows an alternative method for roll-forming high strength steels. In the first stage, the material is deformed elastically, taking care that the curvatures do not introduce a permanent set. High yield strength steels may, in fact, allow a fair transverse curvature of the strip without permanent deformation. The second stage produces a 45° bend, with the edge sweep being minimal. The third stage completes the bend with an allowance for springback (92°-93°). The final stage completes the channel shape. This method requires four stages and probably also one or two intermediate guides, but actual bends are completed in two stages.

6.1.1 ROOFING AND CLADDING SECTIONS

Stress relieved, high strength products such as ZINCALUME® G550 steel and ZINC HI-TEN® G550 steel have been used successfully for many years to produce a corrugated profile. Then the smaller radiused, prismatic profiled shapes such as that used for TRIMDEK® and SPANDEK® were converted to these products, to be followed by flat-panned roofing shapes such as KLIP-LOK® decking. Later there were movements into various accessory shapes including quad gutter.

The significant difference in forming performance between these high strength steels and the now replaced, soft products, ZINCALUME® G300 steel and ZINCFORM® G300 steel, is essentially springback. Further, albeit smaller, increases of springback result from the significant thickness reductions achieved by the substitution of these high strength products.

To compensate for the differences following this product change, the basic concepts of roll design need to be reconsidered. While springback problems can usually be overcome

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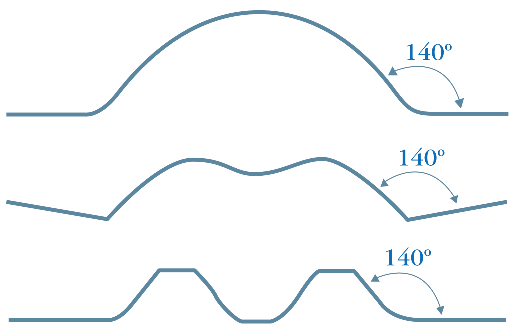
on the tightly radiused, prismatic shapes by overbending techniques (and while these correction methods are not critical on most profiles) the forming principles used become very important where there are flat pans adjacent to the ribs, eg, in the KLIP-LOK® shape.

6.1.2 PREFORMED BUBBLE TECHNIQUE

Roof and wall claddings, made of very thin steel (0.42 mm base or less) with yield strengths well above 550 MPa, allow for even greater transverse deformations in the forming process. One particular profile with prismatic ribs has its strip preformed into bubbles before the actual forming of bends begins *(Figure 15)*. A suitable shape and size of the bubble can be determined only by experience and/or by a trial and error method. Fortunately, the roll segments in pre-forming stages need not be made of hard tool steel; thus they can be readily re-machined or replaced during the trial runs.

Figure 15 – Forming by means of a bubble



6.1.3 OIL-CANNING

Oil-canning is the looseness which can develop for a variety of reasons in the flat pan of a roll-formed panel where it appears as recurring waves of excess material along the panel. This looseness can result from a number of causes and these at times can be difficult to isolate and identify.

One of these causes originates from incorrect roll design or intermesh setting so that the profile shape entering a later stage of the former contains an excessive width of feed or profile segment. As a result this excessive width has to be crowded or crammed into a smaller segment length and one possible result of this action is to generate oil-canning.

A more common cause of oil-canning occurs when forming flat pan profiles from thin high strength products and excessively stretching the feed over roll radii. Such stretching is required to either overcome the high springback of these products or because an incorrect profile shape has been presented at a later stage and must be stretched to produce the specified shape.

When a bend is formed, in say 0.42 mm G550 feed, the bent area both thins and shortens. Thus, in a formed panel, the bend will be slightly shorter in length than the adjacent pan. Should the transverse stress be increased in the profile as the bends are being formed and reformed, the degree of thinning and hence the shortening, increases. Thus where it is important to prevent the oil-canning of adjacent flat pans, bend shortening should be restricted as far as possible. This may mean attention to the design concepts and operating procedures. Some of these areas are as follows:

a) gathering of the strip around ribs by pre-shaping into a much looser shape as shown in Figure 15.

b) provide sufficient width of feed in the initial shaping stages of the forming operation so that the required rib profile can be developed without excessive stretching within these areas. This will concern both roll design and operating techniques.

c) form bends in as few passes as possible and prevent re-rolling as will occur with roll misalignment.

d) use an intermediate stage for guiding and preforming the profiles and if necessary increase distances between stands so that the feed can flow without restraint into the component shapes.

Tension levelling of G550 feed can increase the susceptibility of the feed to shorten at bends. While this processing improves strip flatness and hence the rollformed product for many profile shapes, there may be a need to use a product with modified levelling for those flat pan profiles where freedom from oil canning is required. Residual stresses in the feed after modified levelling result in lower tendency to oil canning. Where there is such a concern, contact should be made with a local BlueScope Steel Limited office.

It is important when selecting product thickness, to recognise that the sheet or flat pan stiffness or ability to resist oil-canning, is directly related to the cube of the sheet thickness, ie,

Stiffness = kT3

Thus a reduction of feed thickness from 0.48 mm to 0.42 mm reduces stiffness by 33% of the original stiffness.

High strength products have been used for applications such as rainwater gutters and a variety of rainwater accessory shapes. When these profiles have sharp bend radii and are adequately stiffened there should be few problems such as oil-canning provided there are no basic roll design problems.

However, when large bend radii are required, as with the quad gutter profile, there are

BLUESCOPE STEEL

very likely to be difficulties in obtaining the necessary shape without having to increase the transverse tension in the profile while setting the quadrant shape. The effect of increasing this transverse tension is to reduce the apparent springback of the feed so that less over-bending is required. However the effect of increasing the transverse tension while bending, is to increase the bend shortening which occurs and it is this shortening which transfers the compressive stress into the adjacent critical flat pan of the gutter. Thus to minimise oil-canning in the quad gutter, forming techniques will be required to set the quadrant shape without causing undue bend shortening.

Other factors that can influence oil-canning are roll eccentricity due to bent spindles or poorly machined rolls, stage to stage misalignment and re-rolling.

6.1.4 RIPPLING OF EDGES

Rippling of edges can be influenced by a large number of parameters within the roll former and in the material.

Geometric considerations such as;

a) Location of holes in section. Holes close to an edge can reduce the material's ability to resist stretching.

b) Unsymmetrical profiles where bend angles are the same but one edge is longer than the other.

c) Unstiffened flanges are more likely to suffer edge wave. The provision of a stiffener close to the edge can hide any edge wave.

Machine conditions include:

a) Uneven forming and pressures, especially on the edge of the profile resulting in stretching of the edge.

b) Uneven pass line height for tooling causing the edge to travel further than the designer intended.

c) Incorrectly set straightening device which over stretches one or both edges *(can be linked with trying to remove longitudinal bow or twist)*.

d) Pre and post roll forming equipment not aligned.

e) Too rapid a forming sequence can cause stretching of the edges of the material.

f) Roll diameter too small. The larger the diameter the greater the forming distance.

Material properties that can influence edge wave are:

a) If the coil has re-crystallised (lower tensile strength) and or thinner edges then this material can be more susceptible to stretching and hence edge wave.

b) Incorrect material selection. If the roll former has been designed for high tensile material and low tensile material of the same thickness is roll formed, then edge wave may occur.

Note also that edge wave can be induced through poor slitting practice.

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